FRS Experiment: Performance of the Cryogenic Stopping Cell for the Low-Energy Branch of the Super-FRS*

M. P. Reiter[1], T. Dickel[1,2], S. Purushothaman[2], P. Dendooven[3], J. Ebert[1], H. Geissel[1,2], E. Haettner[1,2], C. Jesch[1], M. Ranjan[3], W. R. Plaß[1,2], H. Weick[2], F. Amjad[2], S. Ayet[2], M. Diwisch[1], A. Estrade[2], F. Farinon[2], F. Greiner[1], N. Kalantar-Nayestanaki[3], R. Knoebel[1,2], J. Kurcewicz[2], J. Lang[1], I. Moore[4], I. Mukha[2], C. Nociforo[2], M. Petrick[1], M. Pfutzner[2], S. Pietri[2], A. Prochazka[2], A-K. Rink[1], S. Rinta-Antila[4], C. Scheidenberger[1,2], M. Takechi[2], Y. Tanaka[2], J. S. Winfield[2], and M. I. Yavor[5]

[1]Justus-Liebig-Universität, Giessen, Germany; [2]GSI, Darmstadt, Germany; [3]KVI, University of Groningen, Netherlands; [4]University of Jyväskylä, Finland; [5]Institut for Analytic Instrumentation, St. Petersburg, Russia

At the Low-Energy Branch [1] of the Super-FRS at FAIR projectile and fission fragments will be produced at relativistic energies, separated in-flight, range-bunched, slowed down and thermalized in a cryogenic stopping cell (CSC) [2], extracted and delivered to precision experiments at MATS and LaSpec.

The CSC consists of a double-walled vacuum vessel. The outer chamber provides the thermal insulation vacuum for the inner cold chamber, which is filled with typically 100 mbar of ultra pure He at cryogenic temperatures (70-100 K). The ions are thermalized in the He and transported by an electric DC field to the extraction side of the CSC. At this side an RF carpet produces a pseudopotential barrier, to keep the ions from hitting the electrodes, and transports them to an extraction nozzle, from which they are injected in to an low-energy RFQ beam line.

In October 2011 and July/August 2012, the CSC and the MR-TOF-MS [3] were commissioned on-line with the FRS [4] at GSI. For the first time, a stopping cell for exotic nuclei was operated on-line at cryogenic temperatures. Using a gas density almost two times higher than ever reached before for a stopping cell with RF ion repelling structures, various projectile fragments were thermalized and extracted with high efficiencies and short extraction times. In the first experiment, the areal density of the helium gas of the CSC amounted to 5 mg/cm^2 He. The range distribution of a 500 Mev/u ^{223}Th beam in the stopping cell (Fig. 1) was measured by varying the Al degrader in front of the cell and determining the ratio of the number of injected and extracted ^{223}Th. From this measurement a stopping efficiency of $(27 \pm 3)\%$ can be caluclated. The total efficiency for stopping, ion survival and extraction amounted to $(12 \pm 2\%)$, resulting in an extraction and survival efficiency of $(43 \pm 9)\%$.

The extraction time of the stopping cell was measured using short ^{221}Ac ion bunches (4 ms). Fig. 2 shows the ^{221}Ac count rate on the silicon detector behind the stopping cell as a function of the time after injection of each ion bunch. After 48 ms the last ^{221}Ac ions are extracted from the cell, giving an extraction time of only 24 ms for ions stopped in the center of the CSC. This measurement agrees well with the offline result of 25 ms obtained with a pulsed ^{223}Ra source and the expectations from mobility theory of 27.5 ms. With this unique combination of high efficiency and short extraction times the CSC is perfectly suited for new studies of projectile and fission fragments.

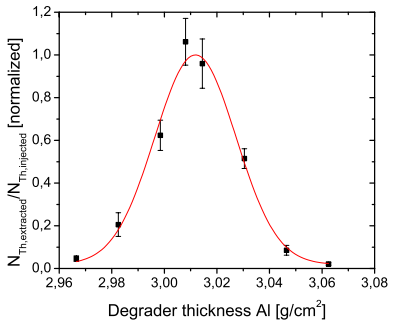

Figure 1: Ratio of the number of injected to extracted ^{223}Th ions of the CSC as a function of the Al degrader in front of the CSC. Note that the ratio has been normalized to unity.

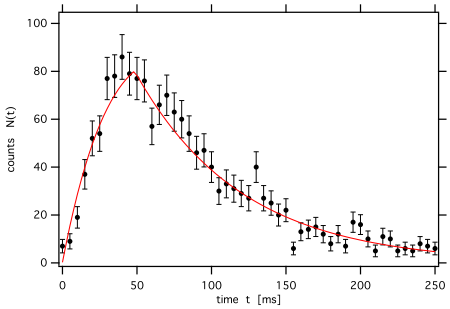

Figure 2: Decay spectra of the α-emitter ^{221}Ac (half life 52 ms) as a function of the time after injection of each ion bunch in the CSC.

References

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